DOCUMENT RESUME

ED 466 694 TM 034 273

AUTHOR	Thatcher, Greg W.; Henson, Robin K.
TITLE	R Squared Shrinkage in Multiple Regression Research: An Empirical Evaluation of Use and Impact of Adjusted Effect Formulae.
PUB DATE	2002-02-15
NOTE	24p.; Paper presented at the Annual Meeting of the Southwest Educational Research Association (Austin, TX, February 14-16, 2002).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	Correlation; *Effect Size; *Regression (Statistics); Scholarly Journals
IDENTIFIERS	*Shrinkage Estimation

ABSTRACT

This study examined research in training and development to determine effect size reporting practices. It focused on the reporting of corrected effect sizes in research articles using multiple regression analyses. When possible, researchers calculated corrected effect sizes and determine if the associated shrinkage could have impacted researcher interpretations. Three human resource development journals were examined from 1998 to 2001, 16 issues for each journal. Regression effects were usually reported, but the inclusion of corrected effects was less frequent. When these effect sizes were reported, they were rarely placed on some theoretical or practical context in relation to previously observe effects. The reader was generally left to draw his or her own conclusion about the practical impact of the effect in the research. (Contains 3 tables and 38 references.) (SLD)

Running head: R^2 SHRINKAGE

R^2 Shrinkage in Multiple Regression Research: An Empirical Evaluation of Use and Impact of Adjusted Effect Formulae

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Paper presented at the annual meeting of the Southwest Educational Research Association, Austin, TX, February 15, 2002.
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Abstract

The present paper examined published research in training and development to determine effect size reporting practices. Specifically, we evaluated the reporting of corrected effect sizes in research articles using multiple regression analyses. When possible we calculated corrected effect sizes and determined if the associated shrinkage could have impacted researcher interpretations.

$\underline{R}^2$ Shrinkage in Multiple Regression Research: An Empirical Evaluation of Use and Impact of Adjusted Effect Formulae

The reporting and interpretation of effect sizes is critical to good statistical practice. As the American Psychological Association (APA) Task Force on Statistical Inference noted (Wilkinson & APA Task Force on Statistical Inference, 1999),

> It is hard to imagine a situation in which a dichotomous accept-reject decision is better than reporting an actual p-value or, better still, a confidence interval. . . . *Always provide* some effect size estimate when reporting a p-value. (p. 599, emphasis added)

The Task Force went on to state, "*Always* present effect sizes for primary outcomes. . . . It helps to add brief comments that place these effect sizes in a practical and theoretical context" (p. 599, emphasis added).

The mandate to "always" report effect sizes is a substantial step beyond the fourth edition of the APA's *Publication Manual,* which only *recommended* reporting of effect sizes in research (APA, 1994, p. 18). Empirical studies, however, have shown that this recommendation had little impact on researchers' inclusion of effect size information in their articles and even less impact on consultation of effects for practical and theoretical context (cf. Henson & Smith, 2000; Vacha-Haase, Nilsson, Reetz, Lance, & Thompson, 2000).

Influenced by the Task Force report, the recent fifth edition of the APA *Manual* (APA, 2001) called the "failure to report effect sizes" a "defect in the design and reporting of research" (p. 5). The *Manual* later observed: "For the reader to fully understand the importance of your findings, it is almost always necessary to include some index of effect size or strength of relationship in your Results section" (p. 25).

Of course, there are many different types of effect size indices. However, most can be grouped as (a) standardized mean differences (e.g., Cohen's *d*) or (b) variance-accounted-for effects (e.g., eta^2, r^2, R^2). Many researchers are familiar with the squared multiple correlation, or R^2, often reported with multiple regression results.

Furthermore, researchers can choose from uncorrected or corrected variance-accounted-for effects. Because general linear model analyses, such as multiple regression, maximize shared variance between variables or sets of variables, these analyses capitalize on the sampling error variance in any given sample to yield the largest possible effect size. This sampling error variance is unique to the sample and unlikely to be present in future samples or the population. Accordingly, these indices (e.g., R^2) are called uncorrected effects sizes.

Corrected effects, however, "shrink" the uncorrected indices based on the degree of sampling error present in a sample to better estimate the real effect in the population. Sampling error (a) increases as sample size decreases, (b) increases as the number of variables in the model increases, and (c) increases as the theoretical population effect decreases. There are numerous corrected effect indices such as omega^2, Adjusted $\underline{R}^2$, epsilon^2, and others. Snyder and Lawson (1992) and Yin and Fan (2001) review several corrected effect formulae. Each index somehow deals with the elements that increase sampling error, resulting in greater "shrinkage" and lower corrected estimates of the true population effect when greater amounts of sampling error are present.

Because corrected effects are better models of the true population effect, they likely give better information as regards the replicability of one's results (a hallmark of good scientific practice). In a Monte Carlo study, Yin and Fan (2001) demonstrated the accuracy of several corrected effect formulae.

Given the general lack of effect size reporting in the literature, one might expect even less frequent reporting of corrected effects. Therefore, the purpose of the present paper was to empirically evaluate the reporting of corrected effects in three human resource, training, and development journals. Because effects are more commonly reported with multiple regression analyses, we examined only regression applications.

The paper will (a) document the frequency of corrected effect reporting in the journals examined, (b) identify the types of corrected effects reported, (c) and estimate the degree of shrinkage present, across studies for various corrected effect formulae presented by Snyder and Lawson (1992) and Yin and Fan (2001) when authors did not report corrected effects. To accomplish the last objective, we calculated several corrected effects using the information provided by authors. This allowed comparison of the possible differences in result interpretation depending on what type of effect was used. It also allowed for empirical investigation of the degree of correction resulting from the corrected effect formulae.

Method

We examined three human resource development journals, Human Resource Development International, Human Resource Development Quarterly and International Journal Of Training and Development. These publications were examined from 1998 to 2001, which totals 16 issues each. Table 1 shows the breakdown of reported effects.

INSERT TABLE 1 ABOUT HERE

Articles were evaluated to determine if they provided sufficient information to calculate corrected effect sizes when they were not provided. In 51 of the 118 instances where uncorrected effects were reported enough information was provided to calculate a corrected effect size. Corrected effect sizes were calculated for these cases using two different formulae, drawn from Yin and Fan (2001): (a) the Pratt formula (see Claudy, 1978) and (b) the Ezekiel (1930) formula. The Ezekiel formula is referred to as Wherry-1 in Yin and Fan (2001). In Yin and Fan's (2001) simulation study, the Pratt (see Claudy, 1978) formula yielded the most accurate R^2 adjustments under several study conditions. The Ezekiel formula (1930) is often employed by major statistical software packages, including SPSS.

Although there are some differences in efficiency of the corrected effect sizes using the formulae offered by Yin and Fan (2001), they point out, "the Pratt formula stands out as the best performer among the 6 formulas, because it performed best under three multicollinearity conditions (unbiased estimates about 91-98% of the time), under three population p^2 conditions (unbiased estimates about 93-96% of the time), and under five *N/p* ratio conditions (unbiased estimates 83-100% of the time)" (p. 214).

Results and Discussion

The reported effect sizes along with the calculated adjusted effect sizes can be seen in Table 2. Table 2 also gives the N and number of predictors in each case, both of which impact the degree of R^2 shrinkage. Further, the amount of shrinkage for each formula is given along with the average of both estimates.

INSERT TABLE 2 ABOUT HERE

Reporting and Interpretation of Effects

Human Resource Development International yielded two articles that used multiple regression analysis.
One article reported both effect sizes and corrected effect sizes. The other article reported only the uncorrected effect size.

Human Resource Development Quarterly articles utilized regression analysis on a more frequent basis. There were nineteen articles found to have used regression analyses during the time period examined. Out of the nineteen, eight reported corrected effect sizes, two of those eight reported only the corrected effects. One of the nineteen articles reported only the change in r^2 values for the stepwise regression, with no reference to overall effect sizes.

International Journal of Training and Development provided six articles using regression analysis during the period evaluated. Only one of the articles reported corrected effect sizes. One other article reported only the regression weights without reporting either corrected or uncorrected effect sizes.

Overall, out of the 27 articles reviewed, 10 articles reported corrected effect sizes (37%). In most cases effect size was listed as a part of the statistical analysis, generally in a summary table. There were a few instances where the authors described the effect size as part of their narrative, such as reported by Hartel, Douthitt, Hartel, and Douthitt (1999): "Seventeen percent of the variance in the mean criterion score was accounted for by the IEI score" (pp. 81-82). There were no instances where any author interpreted the effect size with regard to practical or theoretical relevance in their study.

R^2 Shrinkage

As reported in Table 2, shrinkage was calculated for all 51 instances where sufficient information was provided by the authors. On average across the two formulae, shrinkage ranged from 0.5% to 30.8%. At the high end, Church and Waclawski's (1999) R^2 shrinkage was calculated to be between 26.6% and 30.8%, due primarily to the fact that they used 53 predictors. The use of so many predictors increased the likelihood of increased sampling error.

In their article, Hanpachern, Morgan, and Griego (1998) stated, "Although these predictors are statistically significant, they do not account for a high proportion of the variance" (p. 344). This conclusion would be further supported had the adjusted effect (13.8%) been interpreted rather than the uncorrected effect (17%).

Ensher, Grant-Vallone, and Donaldson (2001) conducted two stepwise regressions. In the first analyses they reported, "Overall, the model explained a significant amount of the variance in job satisfaction (R^2 =.25, F=10.84, p<.001)" (p. 64). The corrected Pratt effect was 23.6%. This shrinkage may not have resulted in Ensher et al. changing their conclusions. However, in their second regression analysis they report similar findings with an uncorrected effect size of 21%. The calculated Pratt effect size for this analysis was 16.3%. This effect could have resulted in a different interpretation.

Tansky and Cohen (2001) conducted a series of regression analyses, and in two instances they used stepwise regression. The first analysis resulted $\underline{R}^2$=0.41, with an adjusted effect of 0.39 (Pratt). Given the magnitude of this effect there seems to be little impact, in this case, on interpretation for the two effects. The second regression analysis resulted in an uncorrected effect size of $\underline{R}^2$=0.21. The adjusted effect was 0.19 (Pratt). This shrinkage likely would make little difference in the interpretation of the data.

Overall, the likely impact of shrinkage on interpretation varied, ranging from minimal difference between estimates to dramatic shrinkage resulting in negative $\underline{R}^2$ values. Of course, the ability to externally evaluate impact on interpretation is limited by a lack of context for the study. The authors themselves are best placed to evaluate this impact, had corrected effects been examined.

Sampling Error and Generalizability

As noted, sampling error represents the degree a given sample is not representative of the population. For any sample short of measuring an entire population, some sampling error is present that potentially limits the generalizability of one's results. Sampling error in multiple regression analyses is affected by several factors, including sample size, the number of predictors, and the theoretical population effect.

Sample size is one of the major factors influencing sampling error. The greater the sample size, the smaller the sampling error. Because a larger sample size is closer to the actual population size, it more closely estimates the population. If the sample consisted of the entire population there would be zero error (of course, we would no longer call it a sample as well). Conversely, the smaller the sample size the greater the error.

The number of predictors also affects sampling error. As the number of predictors increases, the degree of sampling error theoretically increases. This is due to the fact that introducing more predictors introduces more opportunities for error to be accumulated. For example, a given person may have well-measured scores on two predictors, but when a third variable is added, the person's score is not well-measured and is partially due to error. This source of sampling error speaks to the need to have a well-specified model, and to only examine those variables for which one has a theoretical rationale to examine.

Finally, the larger the theoretical population effect, the less sampling error we expect in the sample. This source of error is less intuitive to understand. However, consider the case when the true population effect is R^2=1.00. In this case, it does not matter who you sample from the population, all sample effects will also be 1.00. Conversely, if the population effect was R^2=0.00, you could get sample effects ranging anywhere from 0.00 to 1.00, depending on who was sampled and the relationship of their predictor scores to the dependent variable. In the later case, we expect more sampling error because the results are less trustworthy.

Of course, we never know what the true population effect is. Therefore, the corrected effect formulae tend to use the observed sample effect as an estimate of the population effect. A more reasonable approach might be to include the meta-analytic average of the effects obtained in other studies (along with your study) as the best estimate of the true population effect.

Conclusion

The APA Task Force (Wilkinson & APA Task Force on Statistical Inference, 1999) emphasized, "We must stress again that reporting and interpreting effect sizes in the context of previously reported effects is essential to good research. It enables readers to evaluate the stability of results across samples, designs, and analyses" (p. 599). As suggested by Thompson and Snyder (1997),

> . . . explicitly and reflectively linking research results in a given study to the effect sizes in previous studies is also a vehicle for evaluating result replicability. This can be done prospectively by formulating null hypotheses incorporating specific parameter expectations derived from previous research, as against the contemporary practice of always testing hypotheses of no difference or of no relationship (i.e., what Cohen, 1994, described as "nil" hypothesis testing). (p. 80)

Additionally, the Task Force (Wilkinson & APA Task Force on Statistical Inference, 1999) encouraged authors to "Always present effect sizes for primary outcomes" (p. 599).

Although regression effects tended to be reported in the present review, the inclusion of corrected effects was less frequent. Further, these effect sizes, when reported, were rarely placed in some theoretical or practical context in relation to previously observed effects. Generally, the reader is left to draw his/her own conclusion about the practical impact of the effect in the research.

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Table 1

Reported Corrected and Uncorrected Effects for Multiple Regression Analyses

Journal	# of Articles	# of uncorrected effects reported	# of corrected effects reported
Totals	27	118	45
HRDI	2	17	5
HRDQ	19	82	35
IJTD	6	19	5

Table 2

Reported and Adjusted Effect Sizes

					Shrinkage		
R^2	Pratt	Ezekiel	N	No. of Predictors	Pratt	Ezekiel	Average
0.110	0.105	0.105	552	3	0.005	0.005	0.005
0.060	0.055	0.055	552	3	0.005	0.005	0.005
0.050	0.045	0.045	552	3	0.005	0.005	0.005
0.070	0.065	0.065	552	3	0.005	0.005	0.005
0.100	0.095	0.095	552	3	0.005	0.005	0.005
0.020	0.015	0.015	549	3	0.005	0.005	0.005
0.007	0.002	0.002	549	3	0.005	0.005	0.005
0.010	0.005	0.005	549	3	0.005	0.005	0.005
0.020	0.015	0.015	549	3	0.005	0.005	0.005
0.030	0.025	0.025	552	3	0.005	0.005	0.005
0.010	0.005	0.005	552	3	0.005	0.005	0.005
0.050	0.045	0.045	552	3	0.005	0.005	0.005
0.310	0.273	0.261	30	2	0.037	0.049	0.043
0.570	0.556	0.539	30	2	0.014	0.031	0.023
0.170	0.139	0.137	131	5	0.031	0.033	0.032
0.320	0.254	0.251	131	12	0.066	0.069	0.067
0.128	-0.161	-0.157	207	51	0.289	0.285	0.287
0.210	-0.064	-0.062	207	53	0.274	0.272	0.273
0.140	-0.160	-0.156	207	53	0.300	0.296	0.298
0.230	-0.037	-0.035	207	53	0.267	0.265	0.266
0.210	-0.064	-0.062	207	53	0.274	0.272	0.273
0.110	-0.201	-0.196	207	53	0.311	0.306	0.308
0.140	-0.160	-0.156	207	53	0.300	0.296	0.298
0.160	-0.132	-0.129	207	53	0.292	0.289	0.291
0.220	-0.051	-0.048	207	53	0.271	0.268	0.270
0.170	0.138	0.135	100	4	0.032	0.035	0.034
0.070	0.068	0.068	1250	3	0.002	0.002	0.002
0.140	0.120	0.119	123	3	0.020	0.022	0.021
0.210	0.163	0.160	67	4	0.047	0.050	0.048
0.360	0.354	0.351	146	2	0.006	0.009	0.007
0.400	0.395	0.392	146	2	0.005	0.008	0.007
0.270	0.262	0.260	146	2	0.008	0.010	0.009
0.310	0.303	0.300	146	2	0.007	0.010	0.008
0.290	0.283	0.280	146	2	0.007	0.010	0.008
0.720	0.719	0.716	146	2	0.001	0.004	0.002
0.360	0.354	0.351	146	2	0.006	0.009	0.007
0.410	0.405	0.402	146	2	0.005	0.008	0.007
0.270	0.262	0.260	146	2	0.008	0.010	0.009
0.320	0.313	0.311	146	2	0.007	0.009	0.008
0.280	0.273	0.270	146	2	0.007	0.010	0.009

0.720	0.719	0.716	146	2	0.001	0.004	0.002
0.250	0.236	0.235	366	7	0.014	0.015	0.014
0.210	0.195	0.195	366	7	0.015	0.015	0.015
0.400	0.390	0.388	262	5	0.010	0.012	0.011
0.210	0.193	0.191	262	6	0.017	0.019	0.018
0.330	0.326	0.326	1798	10	0.004	0.004	0.004
0.070	0.045	0.044	112	3	0.025	0.026	0.025
0.129	0.095	0.094	287	11	0.034	0.035	0.034
0.165	0.132	0.132	287	11	0.033	0.033	0.033
0.196	0.165	0.164	287	11	0.031	0.032	0.032
0.384	0.377	0.376	444	6	0.007	0.008	0.008

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